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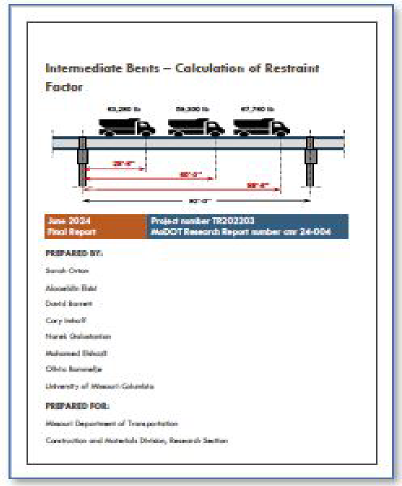
Research Summary


Intermediate Bents – Calculation of Restraint Factor

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Final Report

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MoDOT Research Report number cmr 24-004

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Intermediate Bents – Calculation of Restraint Factor

MoDOT currently uses a k-factor of 2.1 to evaluate the buckling resistance of non-integral intermediate bent columns in prestressed concrete superstructures (assuming a fixed-free condition). However, the restraint provided by longitudinal girders at the top of a column provides additional resistance to the buckling of the column and may allow a reduction in the k-factor to as low as 1.2 (for a fixed – rotationally restrained condition). The project determined the actual level of restraint at the top of the columns so that more accurate values of k-factors can be used. The project developed detailed Finite Element (FE) models (bridges A7957, A8697, and A8279) using ANSYS workbench. The detailed FE models considered the standard design details including the shear keys, dowel bars, roofing felt bond breaker between the diaphragm and bent cap, and joint filler at the edge of the diaphragm. The main source of rotational movement was found to be the connection between the bent cap and diaphragm (Figure 1). The A8697 bridge and the A7957 bridge were used for the FE validation.

Experimental testing was conducted on bridge A8697 via loaded dump trucks. The movements of the bridge were recorded via Digital Image Correlation (DIC) and Linear Variable Differential Transformers (LVDT). The DIC data showed good accuracy in the horizontal direction but was less accurate in the vertical direction due to possible movements in the camera. The DIC rotation data showed that the girder and diaphragm rotated together with about 10 times more rotation than the bent cap and was consistent with the FE model results showing most of the rotational flexibility due to the bent cap to diaphragm connection. Overall, the experimental results generally matched FE model predictions.

"The use of rotational restraint increased the buckling capacity of the concrete columns by 24% to 40%."

A parametric analysis was performed to determine the influence of several key parameters on the rotational restraint at the top of intermediate bent columns. The results showed that the dowel bar area, diaphragm width, and skew angle were all parameters that needed to be considered in the simplified equation to predict the rotational restraint. The girder length and stiffness were found not to be important, and the connection interface is assumed part of standard design. The concrete modulus is important but considered to be a constant for 4000 psi concrete. The column length and stiffness as well as the bent cap length will be directly considered in the k-factor equation.

The project proposes a simplified equation using parameters of dowel bar area, diaphragm width, and skew angle to estimate the level of rotational

restraint based on the dowel bar area, diaphragm width, and skew angle. A comparison showed the predicted rotational restraint was within 10% of that found in the FE models. Using this equation, the k-factor can be determined and buckling analysis of the column can be conducted. Calculations of the k-factors for the modeled bridges showed k-factors less than the assumed 2.0 theoretical for a fixed-pin column with average values around 1.5 and in the case of the steel column bridge a k-factor of only 1.2. A procedure for analyzing telescoping columns was also formulated, in which an effective moment of inertia can be used to treat the column as a uniform diameter. Three examples showed the use of rotational restraint increased the buckling capacity of the concrete columns by 24%-40%. However, for steel HP columns this increase was the most significant at 62%, which changed the controlling buckling mode to the weak axis direction. If buckling capacity controls the design of the column, this could result in a potential cost savings of 20%-30%.

The work culminates in a suggested design procedure to use rotational restraint in the design of intermediate bent bridge columns.

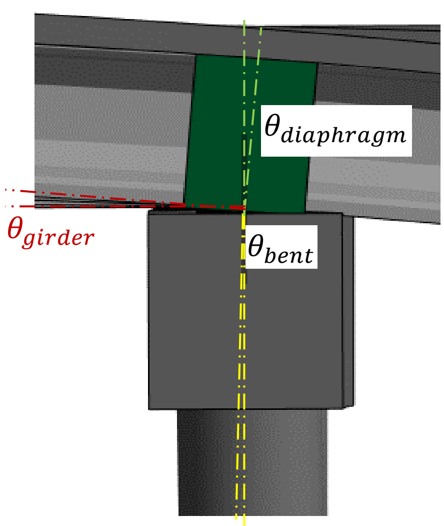

Figure 1: Rotations in intermediate bent.

Project Information

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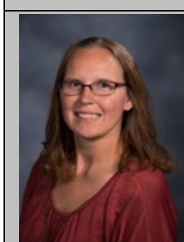

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